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6. AUTHOR(S)
Professor Lemberger

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Ohio State Unviersity Research Foundation
1960 Kenny Road
columbus OH 43210-1063

8. PERFORMING ORGANIZATION REPORT NUMBER

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110 Duncan Ave RMB115
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Evidence is presented supporting the view that the inductance of vortices in films is due to columnar defects. The temperature dependence of the pinning strength is dominated by thermal supercurrent, or "phase", fluctuations rather than by the mean-field temperature dependence of basic superconducting quantities like the Helmholtz free engergy and the magnetic penetration depth.

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1960 Kenny Road
Columbus, Ohio 43210-1063

RESEARCH FOUNDATION

TO: KAREN BUCK
PKA

FAX NUMBER 202·404·7951

Sheets to follow 3

FROM: Arthur. S. Rundle
Associate Director
Office of Grants & Contracts

RE: -94-1-0274
Final Report.

Confirmation

Tel: (614) 292-1673
Fax: (614) 292-4315

e-mail: rundle.1@osu.edu

Final Technical Report for ASSERT grant F49620-94-1-0274, 6/30/94 - 6/29/97.
Due: 9/1/97.
Thomas R. Lemberger, P.I.

Page 1, Section 13, *Abstract*:

This is the final technical report for ASSERT grant F49620-94-1 0274, T.R. Lemberger, Principal Investigator.

We have taken a great deal of data and now understand that the inductance of vortices in films is due to columnar defects, and that the temperature dependence of the pinning strength is dominated by thermal supercurrent, or "phase", fluctuations rather than by the mean-field temperature dependence of basic superconducting quantities like the Helmholtz free energy and the magnetic penetration depth. We have the most data on pure YBCO films and are extending our measurements to oxygen-depleted and chemically doped YBCO films as well as to other materials. In this way we will determine how to improve the vortex pinning properties of YBCO films *via* chemical substitutions.

Main body of report, per AFOSR amendment No. 2 dated 03/27/89.

a) Objectives.

Our primary objective is to understand the dynamics of superconducting vortices created in films of the high-temperature superconductor, $YBa_2Cu_3O_{7-x}$, by application of a magnetic field perpendicular to the film. Of particular interest is the range of fields and temperatures away from the vortex-glass melting transition. Subsidiary objectives included development of a novel apparatus and the associated numerical inversion routines to obtain the relevant vortex parameters of pinning strength and viscosity from measurement of the mutual inductance of coils on opposite sides of the film. The technique permits precise and accurate measurements on films that are unpatterned, and it avoids edge effects.

The technical goal of this project is to determine how to tailor the properties of films of $YBa_2Cu_3O_{7-x}$ to minimize electrical dissipation when such films are operated at high currents in sizable ambient magnetic fields. At present, it is known that YBCO films can be tremendously effective in pinning superconducting vortices, but it is not known what particular feature of the film provides the pinning or whether this mechanism can be enhanced via chemical doping. We intend to find out.

b) Status of research effort.

The experiment is fully operational. We are taking and analyzing data as fast as we can. Our results are providing a much fuller picture of the evolution of vortex pinning with field and temperature than has been produced previously. We have discovered that thermal phase

(supercurrent) fluctuations dominate the dependence of pinning strength on temperature not only in the critical regime near the vortex glass melting transition, but also at the lowest temperatures we have studied, namely, 4K. This is the primary effort of graduate student, Aaron Pesetski. Assistance on film fabrication is provided by another graduate student, Brent Boyce, and undergraduate student James Baumgardner. Due to the unanticipated departure of the original student on the project, the flow of papers is just beginning.

c) Publications.

"*Inductive response of vortices in $Y_1Ba_2Cu_3O_7$ and Sm Ba Cu O films*," Anne E. Cunningham, Master's Thesis, Ohio State University, August, 1995.

"*Vortex pinning in the frozen vortex lattice in $YBa_2Cu_3O_{7-\delta}$ films*," D.G. Xenikos, A.E. Cunningham, T.R. Lemberger, L. Hou, and M.W. McElfresh, Phys. Rev. B 53, 9453 (1996).

"*Numerical modeling and experimental considerations for a two-coil apparatus to find the complex conductivity of finite radius thin films*," Stefan J. Turneaure, Aaron Pesetski, and T.R. Lemberger, currently in final draft form, to be submitted to J. Appl. Phys.

"*Influence of thermal phase fluctuations on the T dependence of the vortex pinning strength in YBCO films*," Aaron Pesetski, Kathleen M. Paget, Brent R. Boyce, and T.R. Lemberger, in preparation. To be submitted to Phys. Rev. B.

d) Personnel.

Thomas R. Lemberger, Prof. of Physics, Principal Investigator.

Anne E. Cunningham, Graduate Research Associate, Physics Ph.D. program.
Aaron A. Pesetski, Graduate Research Associate, Physics Ph.D. program.
Brent R. Boyce, Graduate Research Associate, Physics Ph.D. program.
James E. Baumgardner II, Undergraduate, Honors Program.

e) Interactions.

Presentations:

"Effects of dopants on electrodynamics in oxide superconductors," a seminar given at Wayne State University, April, 1995; Univ. of Cincinnati, May, 1995.

APenetration depth studies on pure and doped superconducting YBCO,@ a seminar given at Ohio State Univ., Oct., 1996; U. Toledo, Nov. 1996; Notre Dame Univ., Nov. 1996.

"Penetration depth studies in pure and doped $YBa_2Cu_3O_{7-\delta}$ films," SPIE conference, "Oxide Superconductor Physics and Nanoengineering II," San Jose, CA, January, 1996.

"Evidence for thermal phase fluctuations in the magnetic penetration depth of YBCO at low temperatures," March Meeting of the APS, Kansas City, MO, 1997.

"Dopants (not impurities) in superconductors," given at the symposium in honor of the retirement of Donald M. Ginsberg, Univ. of Illinois-Urbana, April, 1997.

Consultative functions:

Sample and measurement exchange with Drs. Timothy Peterson and Rand Biggers at Wright-Patterson AFB, Dayton, OH.

Collaboration with a local firm, Superconductive Components, Inc., which is an international manufacturer of bulk superconducting materials such as pressed powder targets for Pulsed Laser Deposition or rf Sputtering of films.

f) Discoveries, *etc.*

The temperature dependence of the vortex pinning strength in films, and probably in bulk materials as well, is dominated by thermal phase, or supercurrent, fluctuations, rather than by the mean-field temperature dependence of the basic superconducting parameters of magnetic penetration depth and Ginzburg-Landau coherence length. The pinning structure in films is columnar rather than point-like or planar.

g) Additional relevant information.

None.